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IS 10661 (1983): Glass Fibre Reinforced Polyester Chemical Resistant Tanks [MED 17: Chemical Engineering Plants and Related Equipment]

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UDC 621·642·34 : 66·026·7 : 678·674·046·364 : 666·189·211

IS : 10661 - 1983

Indian Standard

(Reaffirmed 1999)

SPECIFICATION FOR GLASS FIBRE REINFORCED POLYESTER CHEMICAL RESISTANT TANKS

Chemical Engineering Sectional Committee, EDC 57; Process Vessels Subcommittee, EDC 57 : 2 [Ref: Doc : EDC 57 (3493)]

1. Scope — Covers the design, materials, construction practices and workmanship, performance requirements, inspection and testing of fibreglass reinforced polyester tanks for use in chemical environments, manufactured by hand lay up or contact pressure moulding or filament winding process. It also includes the construction with or without an inner lining of thermoplastics.

1.1 This standard is applicable only to tanks subjected to all of the following conditions:

a) Own hydrostatic head of liquid contents,
b) Freely vented to atmosphere,
c) Above ground,
d) Cylindrical, and
e) Vertical or horizontal.

1.2 It does not apply to tanks which are subjected to any of the following:

a) Internal pressure,
b) Vacuum, and
c) Liquids heated above their flash points.

1.3 The nominal service temperature is 0 to 60°C. However, service temperatures above 60°C and below 0°C may be allowed by supplier - purchaser agreement.

1.4 This standard also does not apply to jacketed tanks and tanks used for transport of liquids or gases.

1.5 This standard covers glass fibre reinforced tanks for chemical service and is not intended to cover selection of exact resin matrix or glass reinforcement combination for use under specific chemical and structural conditions.

2. Definitions

2.1 Unless otherwise specified, for the purposes of this standard the plastics terminology as given in IS : 2828-1964 'Glossary of terms used in the plastics industry', shall apply.

3. Materials

3.1 *Resin System* — The resin system selected, consisting of resin catalyst, accelerators and promotors in definite proportions, shall be of suitable commercial grades which meets the technical requirements of the application. Unless there is a satisfactory service experience with the resin system selected for a particular duty, the suitability of the selected resin system shall be established by appropriate tests as given in IS : 6746-1972 'Unsaturated polyester resin systems for low pressure fibre reinforced plastics'.

3.1.1 Resins shall contain no pigments, colourants, dyes or fillers (except for viscosity control up to 5 percent by mass), or any thixotrotric agent, that may interfere with the visual inspection of the laminate. For external finish, pigments may be used for ultra violet absorption or antimony compounds or other fire retardants for improved fire resistance, by agreement between purchaser and vandor. Such additions may interfere with visual inspection of laminate quality. Where fillers are used special consideration shall be given for the design and manufacture of the laminate.

3.2 *Reinforcing Material* — The reinforcing material shall be a suitable grade of glass fibre having a coupling agent, compatible with the resin used, and suitable for the particular production technique. It shall also be comparable to that used to generate corrosion resistance and physical property design data.

3.3 *Surfacing Materials* — Glass fibre surfacing mats used on the surface exposed to chemical attack shall be commercial grade chemical resistant glass having a coupling agent. This shall apply to the external surface also to take care of corrosion due to elements like weather. An organic veil can also be used by agreement between purchaser and manufacturer.

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3.4 *Thermoplastic Lining Materials* — Unless otherwise agreed, the lining shall to unplasticized polyvinyl chloride (PVC) or polypropylene. Selection shall be on the basis of resistance to process fluid.

3.4.1 The thickness of PVC shall not be less than 3 mm. Sheet should normally be used but pipe may be used for branches and nozzles of small diameter.

3.4.2 The minimum thickness of polypropylene shall be 2 mm except for small dia pipes and branches which may have a thickness of 1·5 mm.

4. Minimum Physical Properties of Reinforced Laminate Layers

4.1 *Contact Moulded Laminates* — Contact moulded laminates shall satisfy the minimum property requirements listed in Table 1 and determined according to IS : 1998-1962 'Methods of test for thermosetting synthetic resin bonded laminated sheets'.

TABLE 1 PROPERTIES OF LAMINATES OF VARIOUS THICKNESS

Property at 23°C	Laminate Thickness, mm			
	5·0	6·5	8·0	10 and up
Ultimate tensile strength *Min*, MPa	65	85	95	105
Flexural strength *Min*, MPa	110	130	140	150
Flexural modulus of elasticity (tangent) *Min*, MPa	4 850	5 500	6 200	6 900

The values given in Table 1 shall apply to laminates incorporating only E glass reinforcement having a glass content by weight within the range 30 to 45 percent.

4.1.1 Laminates that do not meet the minimum values given in Table 1 are considered acceptable provided they are made to afford the same overall strength that would be obtained with a laminate meeting the specified thickness.

Note — If the specified thickness for a laminate is 5 mm, according to Table 1, a minimum tensile strength of 65 MPa is required. By multiplying thickness by minimum tensile strength, value of 0·310 MN breaking load for a 1 m wide specimen is obtained. A laminate having a tensile strength of 48 MPa will therefore, be acceptable in place of the 5 mm requirement, if it has an actual thickness of at least 6·5 mm.

4.2 *Filament Wound Laminates* — The maximum hoop stress for the total laminate (that is, filament winding inner surface and interior layer) shall be limited by the allowable movement (strain) of the tank wall when filled with fluid.

4.2.1 The maximum allowable hoop stress shall be determined by the following formula :

$$\sigma_H = E_t\,(z)$$

where

σ_H = hoop stress, MPa;

E_t = hoop tensile modulus of the total laminate, MPa; and

z = allowance strain, cm/cm.

This equation would give a good approximation of total laminate modulus for values of σ_H of 20 MPa — 41 MPa.

4.2.2 The allowable strain of the tank wall not exceed 0·001 0 cm/cm.

4.2.3 The longitudinal strength of the tanks shall at least be equal to that of a helically wound tank having a maximum angle of wind of 80° (measure from the tank axis, that is 90° is hoop winding).

4.2.4 The minimum required wall thickness of the total tank shall be determined by :

$$t = 9{\cdot}81 \times 10^{6} \frac{\lambda H D}{2 E_{t} z}$$

where

P = pressure, Pa
H = fluid head, m
λ = specific gravity of fluid,
D = inside diameter of tank, m

The thickness shall never be less than 5 mm.

Note — The above calculated wall thickness is for filament wound laminate only. This should not include thickness of inner surface, interior layer and outer surface.

4.2.5 *Heads* — The head shall be able to support a 110 kg load on a 100 × 100 mm area. The minimum thickness shall be 5 mm.

4.2.6 *Bottoms* — The minimum thickness for a flat fully supported bottom shall agree with the following :

Up to and including 1·8 m tank diameter — 5 mm
Over 1·8 and including 3·6 m tank diameter — 6·5 mm
Over 3·6 m tank diameter — 8 mm

Note — Isolated small spots may be as thin as 80 percent of the minimum thickness and not detract from tank performance.

4.3 *Surface Cure* — The cured surface shall have a hardness of at least 90 percent of the resin manufacturer's minimum specified hardness for the cured resin. A tank showing evidence of incomplete cure (such as, appearance, tackiness, resin pick-up by acetone, and low hardness) may be subsequently considered acceptable, if a satisfactory procedure may be agreed between the manufacturer and the purchaser and shown to be fully effective. Hardness may be measured by Bar Col hardness tests or alternatively after placing a cloth soaked with MIVK solvent for 3 to 5 minutes, change of thickness of the resin shall be checked for curing.

4.4 *Vents* — Closed-top tanks shall be positively vented to atmosphere. Minimum vent size shall be equal to the largest outlet or inlet.

5. Construction

5.1 *Laminate Construction* — In the laminate construction there shall be an inner surface, an interior layer, and exterior layer and an outer surface. By agreement between purchaser and manufacturer other laminate construction may be used.

Note 1 — The composition specified for the inner surface and interior layer are intended to achieve optimum corrosion resistance.

Note 2 — By agreement between purchaser and manufacturer different resin systems may be used within the laminate construction (that is, one resin for the inner surface and interior layer and another for filament winding).

5.2 *Inner Surface* — A chemically resistant glass surfacing mat shall be used for the inner surface, which shall be 0·25 to 0·5 mm thick. By agreement between the purchaser and the manufacturer, organic surfacing mat, asbestos or thixotropic resin may also be used.

Note 1 — The resin in such a layer will usually contain less than 20 percent of reinforcing materials. A specific limit is not included because of the impracticability of determining this value in the finished product.

Note 2 — When organic veils like acrylic and polyesters or asbestos are used, the hardness reading of the surface may be lower. This, however, does not necessarily indicate undercure of the surface.

5.2.1 *Interior layer* — The interior layer is reinforced with only non-continuous glass strands, applied in a minimum of 2 plies of chopped strand mat or alternatively, in a minimum of 2 passes by the spray up process. Glass content shall be 25 to 35 percent by weight. If the subsequent exterior layer is to be filament wound the interior layer shall be allowed to set completely so that the corrosion barier may not be squeezed down to a thin layer increasing the glass content. The combined thickness of the interior layer and inner surface shall not be less than 2·5 mm.

5.3 *Exterior Layer, Filament Wound* — The subsequent reinforcement shall be continuous strand rovings in accordance with **4.2.3**, and this in combination with **5.1** and **5.2.1** shall satisfy **4.2.4**. The filament wound construction may be of a tapered wall construction with thickness varying with tank height, providing there requirements are met at any height levels. If additional longitudinal strength are required, other reinforcements like woven fabric, chopped strand mat or chopped strands may be interspersed in the winding to provide additional strength. Glass content of the filament wound position shall be 50 to 80 percent by weight.

5.4 *Exterior Layer, Contact Molded* — The exterior layer or body of the laminate shall be of chemically resitant construction suitable for the service and providing the additional strength necessary to meet the tensile and flexural requirements. Where separate layers such as mat, cloth or woven roving are used, all layers shall be lapped a minimum of 25 mm. Laps shall be staggered as much as possible. If woven roving or cloth is used, a layer of chopped strand glass shall be placed as alternate layers. The exterior surface shall be relatively smooth with no exposed fibres or sharp projections. Hand work finish is acceptable, but enough resin shall be present to prevent exposed fibre show.

5.5 *Outer Surface* — For added resistance to chemical exposure (spillage), an exterior surface of chopped glass or surfacing mat, or both, made from either glass or organic fibres with resin rich coating, may be employed, as agreed upon between manufacturer and purchaser.

5.6 *Appearance* — The surface exposed to the environment shall be free of cracks and crazes with a smooth finish and with an average of not over 20 pits per square meter provided the pits are less than 3 mm in diameter and not over 0·8 mm deep and are covered with resin to avoid exposure of inner surface, and reinforcement. Some wrinkles are permissible, provided their surface is smooth and free of pits.

5.7 *Intermediate Layer* — The finished laminate shall be as free as commercially practicable from visual defects, such as foreign inclusion, dry spots, air bubbles, pinholes, pimples and delamination.

5.8 *Exterior* — The exterior surface shall be relatively smooth, with no exposed fibres or sharp projections. Hand work finish is acceptable but enough resin shall be present to prevent exposed fibre show.

The outside surface of the tank shall not be pigmented, painted or dyed unless by agreement between manufacturer and purchaser.

6. *Joints* — Where tanks are manufactured in sections and joined by use of a laminate bond, the joint shall have at least the thickness of the heaviest section being joined. The reinforcement shall extend on each side of the joint centered on the joint, a sufficient distance to make the joint at least as strong as the tank wall and shall not be less than the minimum joint width specified in Table 2. The width of the first layer of the joint lay up shall be 75 mm minimum and successive layer shall uniformly increase in width.

The reinforcement shall be applied on both inside and outside with the interior layer considered only as a corrosion barrier and not structural material. The inner reinforcement shall consist of a minimum of 2 layers of 450 g/m^2 followed by a 0·25 to 0·5 mm of surfacing material (*see* 5.2).

TABLE 2 MINIMUM JOINT WIDTH FOR JOINING VARIOUS PARTS OF TANK

Tank wall thickness, mm	5	6·5	8	9·5	11	12·5	14	15·5	17	18·5
Minimum of outside overlay width, mm	100	100	125	150	175	200	225	250	275	300
Minimum of inside overlay width, mm	100	100	125	125	150	150	150	150	150	150

Note — These figures are for contact moulded tanks and for filament wound shells, the tank wall thickness readings should be taken as the contact moulded construction having an equivalent longitudinal strength.

6.1 The joint shall be as crevice free as is commercially practicable. Crevices between the joined pieces shall be filled with resin or thixotropic resin paste leaving a smooth surface for lay up. All cut edges shall be coated with resin avoiding glass fibre exposure.

6.2 The surface of parts to be joined shall be roughed by sander or sand blasting and shall be free from foreign materials, such as wax, glue, grease, etc. The surfaces shall be clean and dry before lay up. The entire roughened area shall be coated with resin when the joint is made.

6.3 *Heads*

6.3.1 Heads may be fabricated integrally with the tank wall or separately by contact moulding. They may also be integrally attached or removable and may be of any shape. Heads fabricated by contact moulding shall satisfy the mechanical property requirements of **4.2.5**. In all cases the interior layer and surface shall present the same corrosion resistant surface to the environment as the tank wall (*see* **5.2** and **5.2.1**). Joints between shell wall and head shall conform to **6**.

6.3.2 For integral heads shell and bottom reinforcement shall overlap a minimum of 100 mm.

6.3.3 For separately moulded heads, the minimum straight flange length shall be 100 mm.

6.3.4 The knuckle area shall be reinforced to the same width and thickness as a joint (*see* Table 2). It shall be centred over the knuckle and taper uniformly into the bottom thickness over a distance of not less than 150 mm.

6.3.5 The knuckle shall not be less than 25 mm.

6.3.6 Flat bottom tanks must be supported on a flat surface or on properly spaced dunnage. A flat and reasonably soft surface like confined sand, cinder filled pad, plywood surfaced concrete or a concrete grout may be used. When full bottom support is not possible, like conical or rounded bottom heads, special bottom design is required.

6.4 *Fittings* — Standard flanged nozzles shall be fabricated from either contact moulded polyester pipe and a suitable flange, integrally moulded pipe and flanges, or polyester machine made pipe and a suitable flange. Vents do not require flanges but they shall use either contact moulded integrally moulded or machine made pipes.

Note — Standard side entry manholes shall be treated as large diameter nozzles.

6.4.1 *Pipe* — The pipes used for flanges shall have minimum wall thickness as given in Table 3.

TABLE 3 PIPE FOR NOZZLE ASSEMBLY

Pipe Size I.D. mm	Minimum Wall Thickness mm	Pipe Size I.D. mm	Minimum Wall Thickness mm
50	5	350	6·5
75	5	400	6·5
100	5	450	6·5
150	5	500	6·5
200	5	600	6·5
250	5	750	8·0
300	5	900	9·5
		1050	9·5

6.4.2 *Flanges* — Flat faced with full face soft gaskets, shall be of the minimum thickness given in Table 4.

6.4.3 *Flange Attachment* — The minimum flange shear surface shall be four times the flange thickness indicated in Table 4. The thickness of flange hub reinforcement measured at the top of the fillet radius shall be at least half of the flange thickness and shall be tapered uniformly along the length of hub reinforcement as shown in Fig. 1. The fillet radius, where the back of the flange meets the hub, shall be 10 mm minimum.

6.4.4 *Flange Face* — The flange face shall be perpendicular to the centreline of the pipe within 1 deg and shall be flat to ± 0·75 mm up to and including 450 mm diameter and ± 1·5 mm for larger diameters unless otherwise specified.

Note — Other flanges agreed upon between the manufacturer and the purchaser are acceptable provided that they produce a tight joint at twice the operating pressure.

6.5 *Nozzle Installation* — At assembly, there shall be a minimum dimension of 75 mm from the wall of the tank to the flange hub for compression moulded flanges or to the flange back for hand

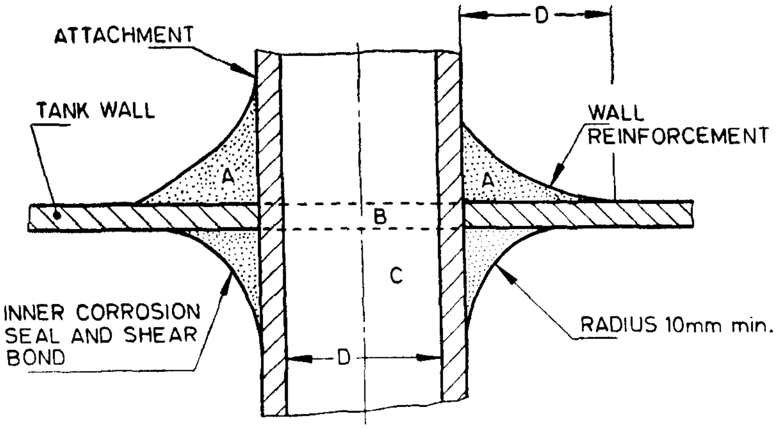


FIG. 1 WALL REINFORCEMENT

TABLE 4 FLANGES FOR NOZZLE ASSEMBLY

Pipe Size, O.D. mm	Minimum Flange Thickness mm
50	12·5
75	12·5
100	12·5
150	12·5
200	14·0
250	17·0
300	18·5
350	20·0
400	21·5
450	23·0
500	25·0
600	28·0
750	35·0
900	45·0
1 050	50·0

lay-up flanges. Where angular loadings are anticipated, nozzles shall be supported by a suitable gusseting technique.

6.5.1 Standard orientation shall have bolt holes stradeing principal centreline of the vessel unless otherwise specified.

6.5.2 Location of nozzles on the vessel shall be held to ± 6·5 mm unless otherwise agreed upon by the manufacturer and purchaser. Tolerance on angle of nozzle centreline shall be within 1 deg of specification.

6.6 *Reinforcement of Wall* — Thickness of overlay shall not be less than the wall thickness specified for hand lay-up pipe in Table 3. The length of nozzle shear band area shall be according to Fig. 2, 3 and 4.

6.7 *Stiffeners* — Open top vertical tanks shall be constructed with a flange or a ring bonded to the top of the shell. Alternatively, the shell should be overwound or overlaid to provide sufficient rigidity for retaining the shape of the tank.

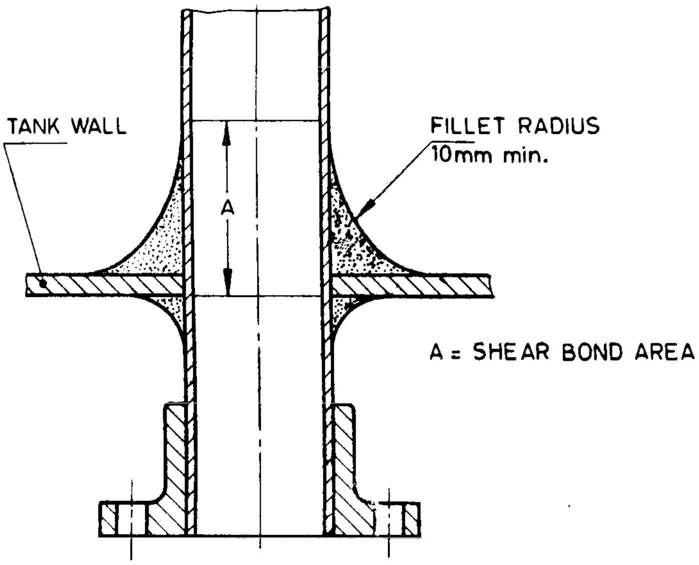


FIG. 2 INSTALLED NOZZLE WITH PIPE PENETRATION

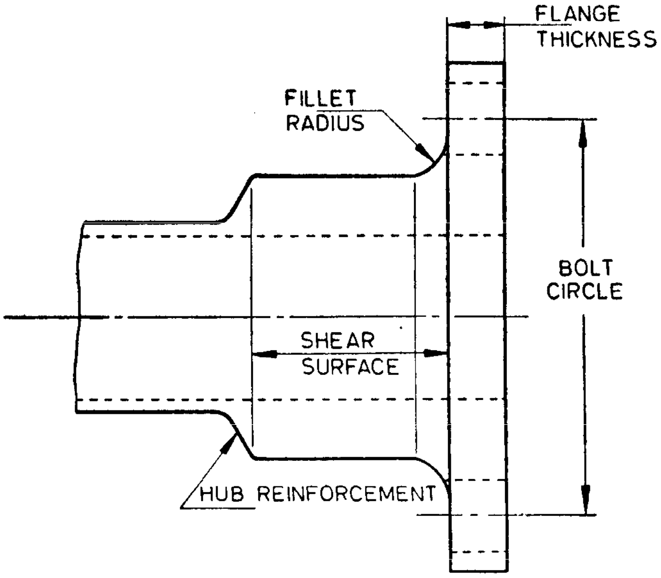


FIG. 3 NOZZLE

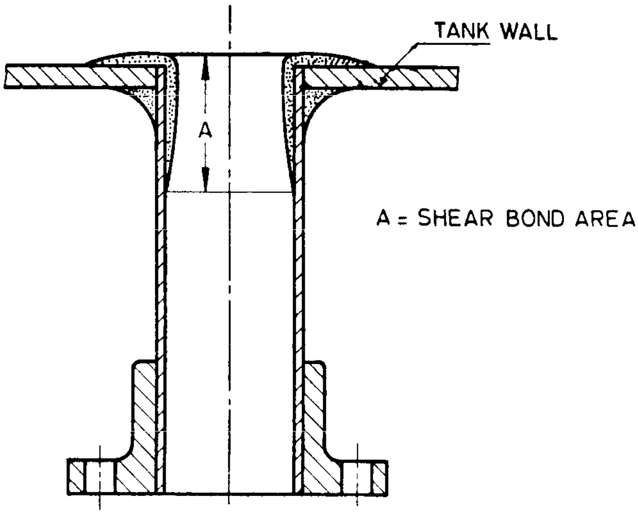


FIG. 4 INSTALLED NOZZLE WITHOUT PIPE PENETRATION

6.7.1 External stiffeners, when used may be made with additional circumferential windings. Overwound or overlaid cores are the permissible alternatives provided they are completely enclosed in reinforced plastic.

6.8 *Hold Down Lugs* — Hold down lugs shall be provided on all tanks for outdoor service.

6.9 *Lift Lugs* — Tanks shall be equipped with suitable handling devices as agreed upon by manufacturer and purchaser.

7. Manufacturing Procedure

7.1 *General* — The manufacturer shall eliminate as many variables as possible to ensure consistency in both materials and fabrication, and shall provide adequate supervision at all stages of manufacture.

7.2 *Lay-up* — The requisite amounts of resin, catalyst or hardener and any other ingredient such as accelerator, or permitted filler shall be accurately measured and thoroughly mixed. The amounts of mixed resin and reinforcement used in each layer of the laminate and the number and type of layers applied shall be recorded, and the records shall be made available to the purchaser or Inspecting Authority.

Whilst good rolling is essential, excessive rolling pressure should be avoided so as not to disturb the distribution of the reinforcement or to break the fibre strands.

The manufacturer shall ensure that good adhension is obtained between successive layers of the laminate and between the shell and added fittings either by appropriate scheduling of the manufacturing operation or by removing the surface of the cured resin, to expose the fibres.

Adjacent pieces of reinforcement shall be overlapped by not less than 50 mm. The edges shall be worked out by brushing with a stippling action and all joints shall be staggered through the thickness of the laminate.

When directionally biased reinforcement is used care shall be taken to ensure that the high strength fibres are adequately aligned in the correct direction to give the required strength.

The number, size and distribution of air bubbles, pits or inclusions shall be not greater than as agreed between the purchaser and the manufacturer on the basis of previously submitted samples.

Any spillage, drips or runs (which may flake loose) shall be suitably removed.

All surfaces exposed to the vessel contents shall be finished smooth and free from crazing or cracks; any such defects shall be ground out and repaired by an agreed method.

All surfaces shall have a reasonably smooth contour and irregularities which may cause high local loads shall be suitably repaired.

7.3 *Thermoplastics Liners* — All PVC sheet shall be stress-relieved in an oven at a temperature between 120°C and 140°C for an appropriate time. Stress-relieving of extruded pipe (used as part of the lining) may sometimes be necessary and requires special consideration.

Thermoplastics linings should preferably not be worked at temperatures below 15°C because of the possibility of cracking at lower temperatures.

All sheet forming operations requiring high deformation, such as right-angled folds or small radius bends, shall be performed hot.

The layout of the lining sheet should be arranged to avoid welds in corners. Lap welds are not permitted.

All welders engaged on the fabrication of vessels and tanks shall be approved by the purchaser before fabrication commences.

Before welding of the sheet material commences the edges to be welded, together with the filler rod, shall be suitably cleaned. In addition, glass backed polypropylene shall have the glass backing stripped back for a distance of 3 to 6 mm on either side of the weld to ensure that no glass filaments are included in the welded joint.

All sheet welding shall be done by the hot gas-filler rod technique with the exception of polypropylene which may be hot-plate welded by agreement. For hot gas-filler rod welding nitrogen shall preferably be used but compressed air is permissible provided it is free from moisture, dirt and oil. In all cases the grade of material of the filler rod shall be identical to that of sheet material being welded, unless otherwise agreed.

All welds shall be fully penetrating and free from notches and pinholes and shall have at least 90 percent of the strength of the parent material. The permissible number, size, type and distribution of weld defects and the method of repairing any such defects shall be by agreement.

7.4 The test piece shall incorporate a 300 mm long butt weld made by jointing two pieces of the material to be used for the lining, each 300 mm long and 125 mm wide. The weld shall be made in the same way as the production welds and shall include at least one stop and start in each run. Weld procedure for the test welds shall comply with **7.3**.

After completion, the test weld shall be examined visually and by the use of a high frequency spark tester giving a minimum peak voltage of 20 kV. Any weld showing evidence of notches, lack of fusion or pinholes shall be rejected.

8. Inspection and Test Procedure — Mechanical and physical properties shall be determined on specimens cut from flat laminates, prepared in the same construction and by the same techniques as the process equipment (preferably cut out from the same equipment). In all cases the average value of the indicated number of specimens shall be used to determine conformance with the detailed requirements.

9. Tests

9.1 *Glass Content* — The glass content shall be determined in accordance with Appendix A except that low temperature preignition prior to replacement in muffle furnace is recommended. The average for five specimens shall be taken as the glass content (50-75 percent).

9.2 *Tensile Strength* — Tensile strength shall be determined in accordance with IS : 8543 (Part 4/Sec 1) 'Methods of testing plastics : Part 4 Short term mechanical properties, Section 1 Determination tensile properties' (410 — 1180 MPa).

9.3 *Flexural Strength* — Shall be determined in accordance with Appendix B.

9.4 *Hardness* — The Barcol impressor shall be used to determine hardness.

9.5 *Chemical Resistance* — Shall be determined in accordance with Appendix C.

10. Inspection Stages — Unless otherwise agreed between manufacturer and purchaser, inspection shall include the following stages as appropriate :

a) Inspection of workshop conditions where manufacture will be carried out;
b) Inspection of work record relating to the control and issue of material, resin mixing, etc. for each tank or vessel constructed;
c) Identification of the materials of construction and their storage condition;
d) Approval of weld procedures and welders (**7.3**);
e) Witnessing of spark tests on welds in thermoplastic linings where these are incorporated (**7.4**);
f) Examination during hand lay up, spray application winding, die moulding and jointing of resin glass laminates;
g) Examination of any repairs carried out during construction;
h) Examinations on completion of construction, during hydrostatic testing and using transmitted light during inspection before a pigmented coat, if agreed between manufacturer and purchaser, is applied;
j) Examination of other constructional requirement as specified in the order and in this standard;
k) Measurement of strain during hydraulic testing;
m) Checking of tolerances on inside diameter, height and bottom plate distortion. In consultation with manufacturers the following table may be completed :

Inside Diameter mm	Tolerances mm		
	Inside Dia	Height	Distortion of Bottom Plate
Up to 2 000			
Over 2 000 up to 4000			
Over 4 000			

11. Certification Marking — Details available with the Indian Standards Institution.

APPENDIX A

(*Clause* 9.1)

GLASS CONTENT

A-1. Weigh the specimen (25 mm × 25 mm) on an analytical balance in a previously weighed, and ignited crucible.

A-2. Place the specimen in the furnace at a temperature not greater than 340°C. Raise the temperature of the furnace to 565 ± 28°C, at a rate that will not cause blowing or loss of inorganic filler. The specimen and crucible shall be ignited at this maximum temperature to constant weight (2 to 6 hour depending on the thickness), and allowed to cool in a desicator. The loss in weight shall be determined by weighing the residue.

A-3. Calculation — The glass content shall be calculated as follows :

$$\text{Glass content, weight percent} = \left[\frac{(W_0 - W_1)}{W_0}\right] \times 100$$

where

W_1 = loss in weight, and
W_0 = original weight.

APPENDIX B

(*Clause* 9.3)

FLEXURAL PROPERTIES

B-1. Apparatus

B-1.1 *Testing Machine* — A properly calibrated testing machine in which the error in the load measuring system shall not exceed ± 1 percent of maximum load expected to be measured. The load-indicating mechanism shall be essentially free from inertial lag at the crosshead rate used.

B-1.2 *Loding Noses and Supports* — These shall have cylindrical surfaces. In order to avoid excessive indentation or failure due to stress concentration directly under the loading nose, the radius of the nose and supports shall be at least 3·2 mm for all specimen. The arc of the loading nose in contact with the specimen shall be sufficiently large to prevent contact of the specimen with the sides of the nose.

B-2. Test Specimen — The specimen may be cut from sheets, plates or moulded shapes, or may be moulded to the desired finished dimensions.

B-2.1 At least five specimens shall be tested for each sample.

B-3. Procedure — A bar of rectangular cross section is tested in flexure as a beam. The bar rests on two supports and is loaded by means of a loading nose midway between the supports.

B-3.1 *Conditioning* — Condition the specimen at 23 ± 2°C and 50 ± 5 percent relative humidity for 40 h prior to test.

B-3.2 Measure the width and depth of the specimen to the nearest 0·03 mm at the centre of the support span. Calculate the rate of cross head motion as follows and set the machine for the calculated rate,

$$R = ZL^2/6d$$

where

R = rate of crosshead motion, mm/*Min*;
L = support span, mm;
d = depth of beam, mm; and
Z = rate of straining of the outer fiber mm/mm *Min*
= 0·01

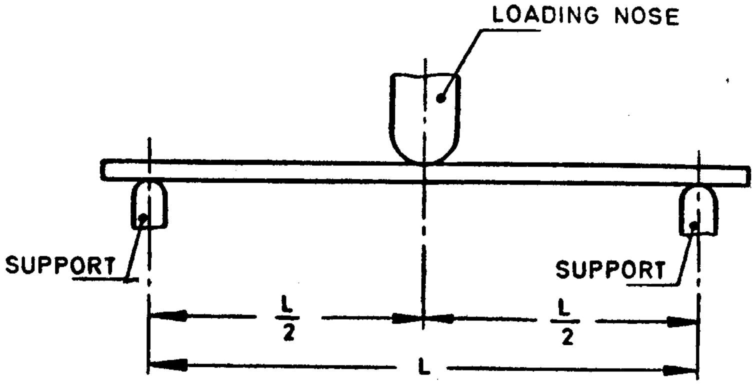
B-3.2.1 Align the loading nose and support so that the axes of the cylindrical surfaces are parallel and the loading nose is midway between the supports. Center the specimen on the supports, with the long axes of the specimen perpendicular to the loading nose and supports.

B-3.2.2 Apply the load to the specimen at the calculated crosshead rate, and take simultaneous load-deflection data. Measure the deflection either by a gauge under the specimen in contact with it at the center of the support span, the gauge being mounted stationary relative to the specimen support, or by measurement of the motion of the loading nose relative to the supports. Load deflection curves may be plotted to determine the flexural yield strength. Terminate the test if the maximum strain in the outer fibres has reached 0·05 mm/mm. The deflection at which this strain occurs may be calculated by letting r equal 0·05 mm/mm.

$$D = rL^2/6d$$

where

D = midspan deflection, mm;
r = strain, mm/mm;
L = support span, mm; and
d = depth of beam; mm.



Note — (a) Minimum radius = 3·2 mm; (b) Maximum radius of supports = 1·5 times specimen depth, maximum radius of loading nose = 4 times specimen depth.

FIG. 5 ALLOWABLE RANGE OF LOADING NOSE AND SUPPORT RADII FOR SPECIMEN 6·4 mm THICK

APPENDIX C

(*Clause* 9.5)

CHEMICAL RESISTANCE

C-1. Apparatus

C-1.1 *Micrometer* — A micrometer suitable for measurement to 0·025 mm.

C-1.2 *Containers* — Wide mouth glass jars of sufficient capacity fitted with plastic-lined metal screw caps for low temperature tests involving solutions or solvents of low volatility.

C-1.3 *Constant* — A temperature oven or liquid bath capable of maintaining temperature within a range of ± 2·2°C.

C-1.4 *Flexural Properties Testing Apparatus* — As given in Appendix B.

C-1.5 *Impressor Type Instrument*

C-1.6 *Analytical Balance* — The balance shall have adequate capacity and be suitable for accurate weighing to 0·000 1 g.

C-1.7 *Desiccator*

C-1.8 *Heat Resistant, Non-Reactive Crucibles*

C-1.9 *Muffle Furnace*

C-2. Test Specimen — Prepare laminates, using identical reinforcement in all the specimens as given in C-2.1.

C-2.1 The standard resin-glass laminate from which test specimen are out shall be moulded as given in C-2. Glass content shall be 25 ± 2 weight percent based on 1·1 sp. gr. cured resin, determined by weight loss on ignition of four 25 × 25 mm specimens. Glass content shall be determined in accordance with Appendix A. Dimensions of the standard laminate shall be 660 × 840 mm.

C-2.2 Specimens for immersion in test solutions shall be 100 × 130 × 32 mm cut from standard laminate.

C-3. Procedure

C-3.1 Condition the sample at 23 ± 2°C and 50 ± 5 percent relative humidity for 40 h prior to test. Immediately after conditioning, measure the thickness of the specimen to the nearest 0 025 mm at the geometric centre of each of the intended specimen 25 × 100 mm.

C-3.2 Determine the Barcol hardness by taking 10 readings and recording the average of the specimen. The total number of specimen per container is not limited except by the ability of the container to hold the specimen without touching each other or the container. The specimen must always be completely immersed. Add a minimum of 750 ml of test solution for each specimen and place the closed container in a constant temperature oven adjusted to the required temperature or in a suitably adjusted liquid bath. Examine the specimen after 30, 90, 180 days and 1 year of immersion to determine the rate of attack. The test may be terminated if the specimen decomposes. If the specimen has not disintegrated, they are removed from the solution, rinsed with water, and wiped dry prior to measuring Barcol hardness.

C-3.3 Run flexural tests in accordance with Appendix B and record the maximum load.

C-4. Calculations

C-4.1 *Barcol Hardness Change* — Tabulate a graph employing the actual hardness readings of the specimen broken at a given temperature, plotting the hardness as ordinate and the test period, in days, as the abscissa. The graph will indicate whether a particular specimen will approach constant hardness with time.

C-4 2 *Change in Flexural Strength* — Calculate to the nearest 0·1 percent, the percentage decrease or increase in flexural strength of the specimen during immersion for each examination period, taking the flexural strength after conditioning as 100 percent.

$$\text{Change in flexural strength, percent} = \left[\frac{(S_2 - S_1)}{S_1}\right] \times 100$$

where

S_1 = flexural strength of specimen after conditioning, and
S_2 = flexural strength of specimen after test period.

Construct a graph employing the average percentage of change in flexural strength of the specimen broken at a given examination period after immersion in a particular test solution at a given temperature.

EXPLANATORY NOTE

In the preparation of this standard assistance has been derived from BS 4994-1973 'Vessels and tanks in reinforced plastics' issued by British Standards Institution.

Printed at Delhi Printers Delhi, India